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(54) **OPTIMIZED INDEX USAGE FOR DATA RESTORE**

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USPC **707/674**; 707/686

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CPC . G06F 11/1451; G06F 11/1469; G06F 3/065; G06F 17/30091; G06F 17/30194; G06F 17/30309
USPC 707/679, 647, 654, 646, 638, 639, 645, 707/649
See application file for complete search history.

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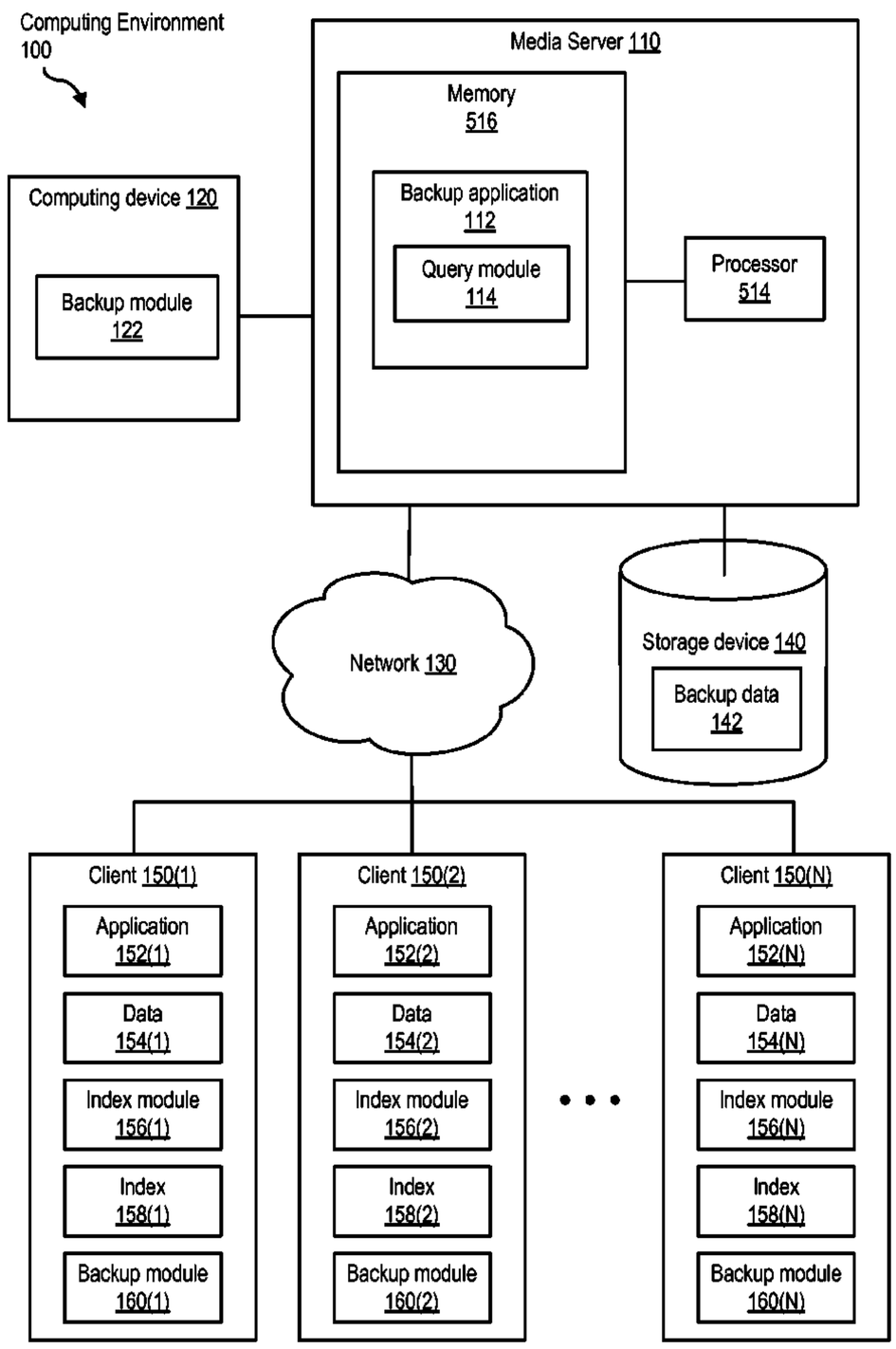
(57) **ABSTRACT**

Various systems and methods for restoring data using indexes. For example, one method involves receiving a request that includes a restore criterion. The method involves identifying a storage object in a backup storage device that meets the restore criterion, in response to the request. Detecting the identity of the storage object involves sending a query with the restore criterion to a client computing device that includes an index. The method also involves responding to the request with information identifying the storage object.

20 Claims, 6 Drawing Sheets



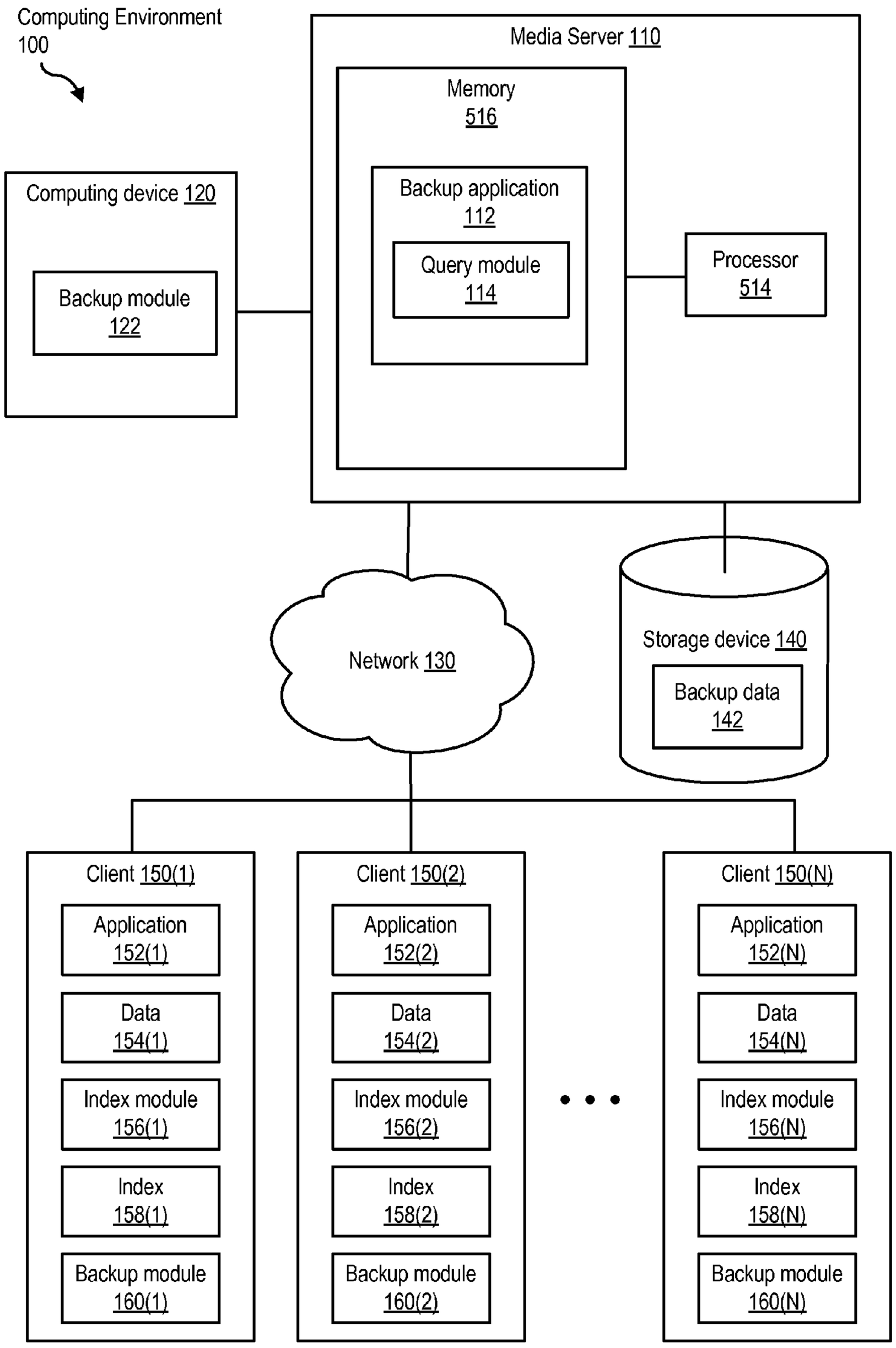

Computing Environment
100
Media Server 110
Memory
516
Backup application
112
Query module
114
Processor
514
Computing device 120
Backup module
122
Network 130
Storage device 140
Backup data
142
Client 150(1)
Application
152(1)
Data
154(1)
Index module
156(1)
Index
158(1)
Backup module
160(1)
Client 150(2)
Application
152(2)
Data
154(2)
Index module
156(2)
Index
158(2)
Backup module
160(2)
Client 150(N)
Application
152(N)
Data
154(N)
Index module
156(N)
Index
158(N)
Backup module
160(N)

FIG. 1

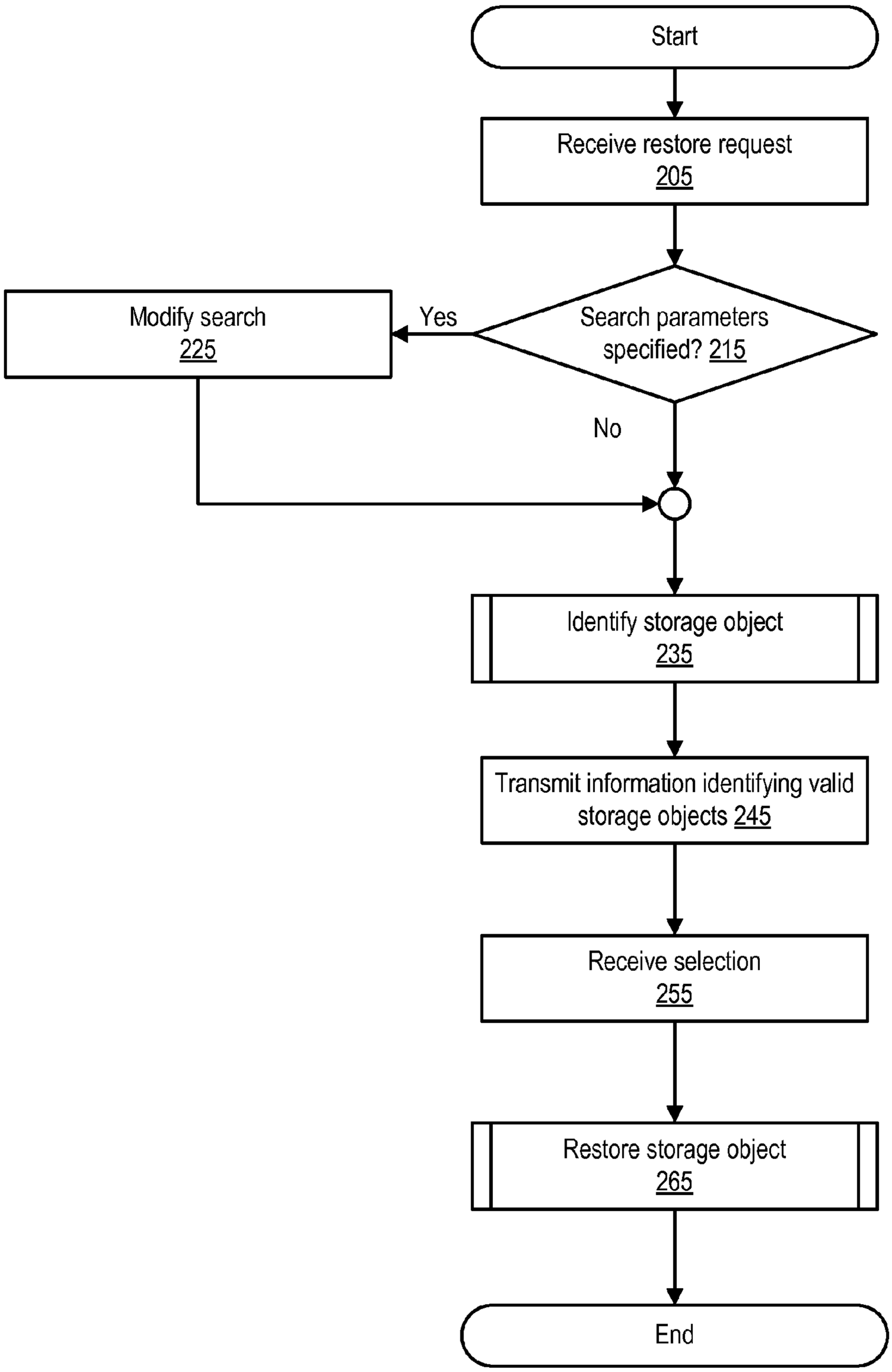

Start
Receive restore request 205
Search parameters specified? 215
Yes
Modify search 225
No
Identify storage object 235
Transmit information identifying valid storage objects 245
Receive selection 255
Restore storage object 265
End

FIG. 2

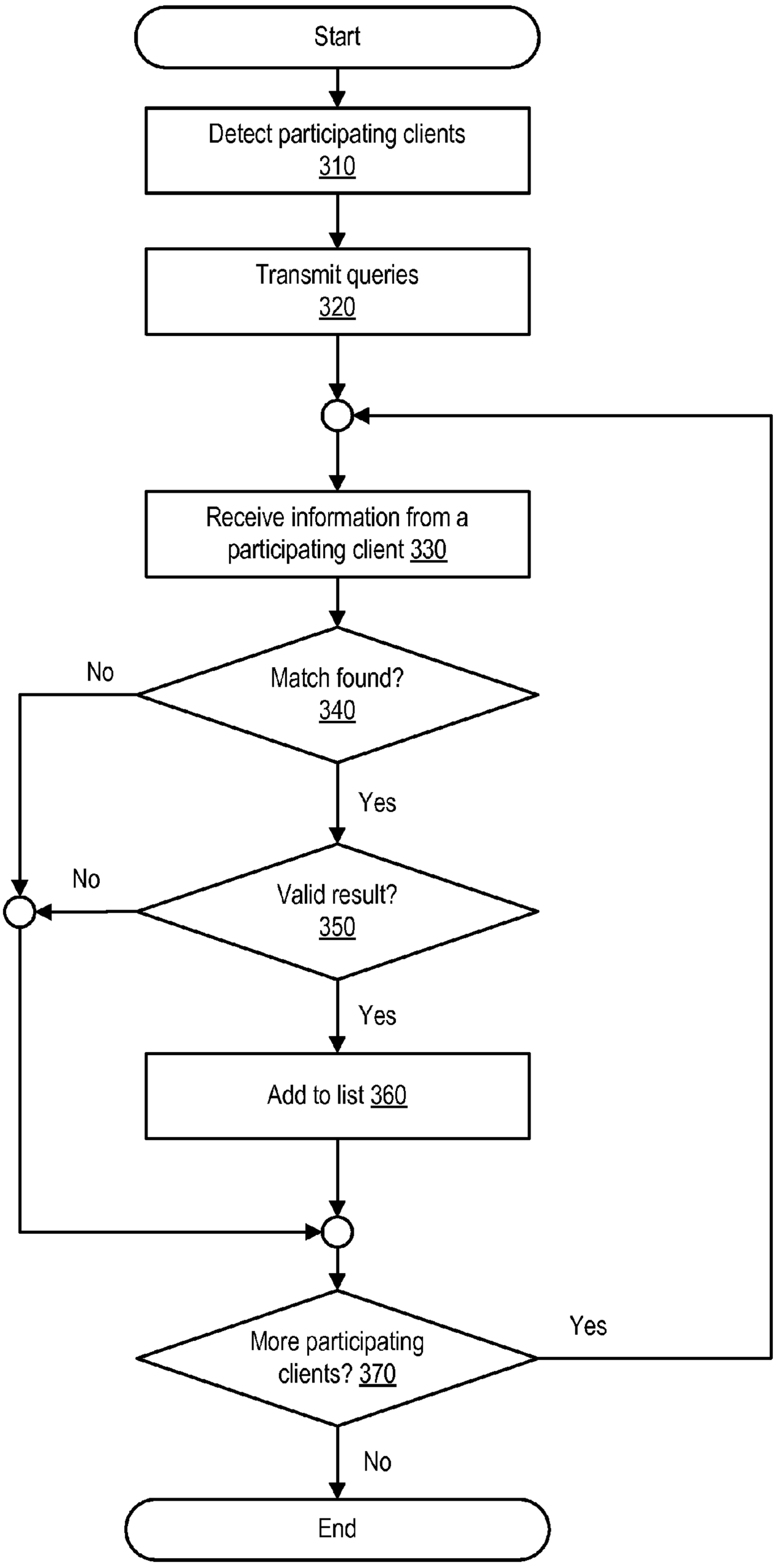

Start
Detect participating clients 310
Transmit queries 320
Receive information from a participating client 330
Match found? 340
No
Yes
Valid result? 350
No
Yes
Add to list 360
More participating clients? 370
Yes
No
End

FIG. 3

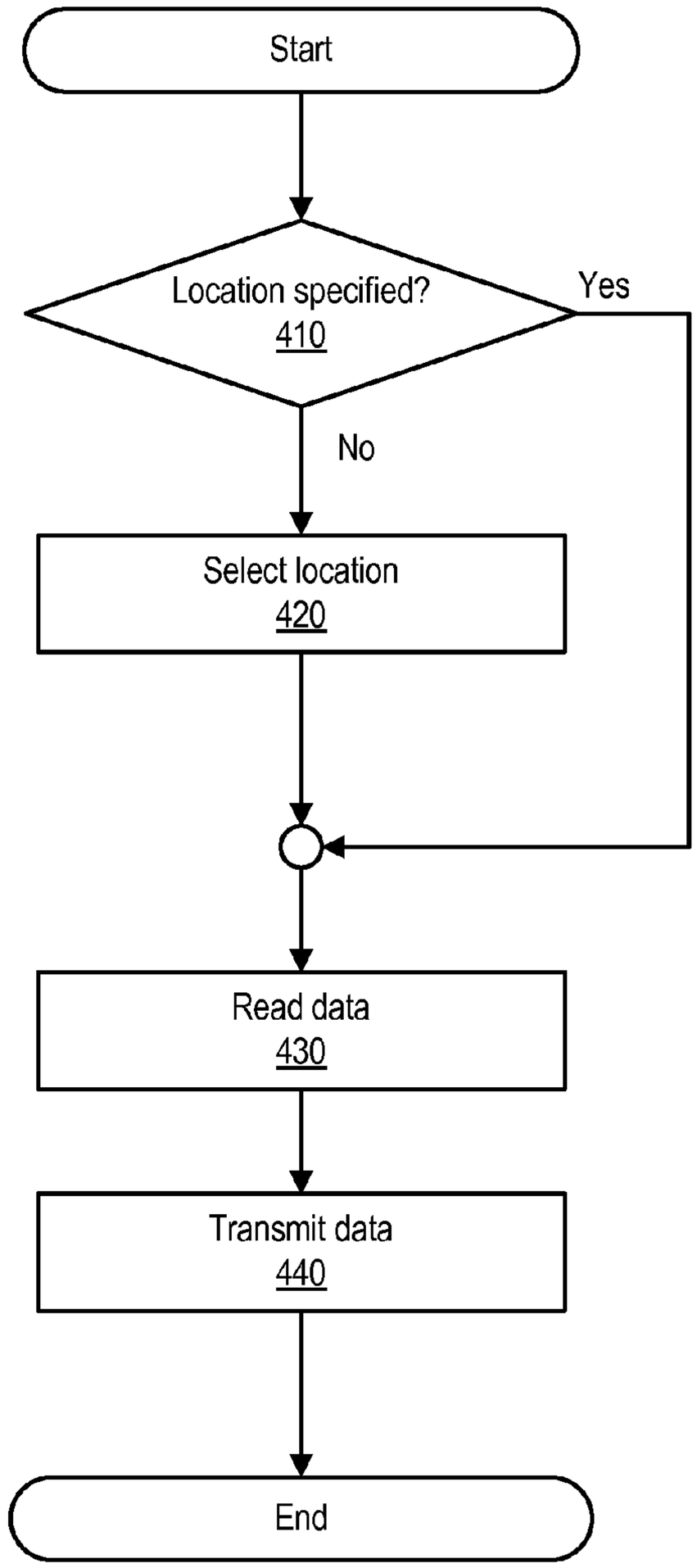

Start
Location specified?
410
Yes
No
Select location
420
Read data
430
Transmit data
440
End

FIG. 4

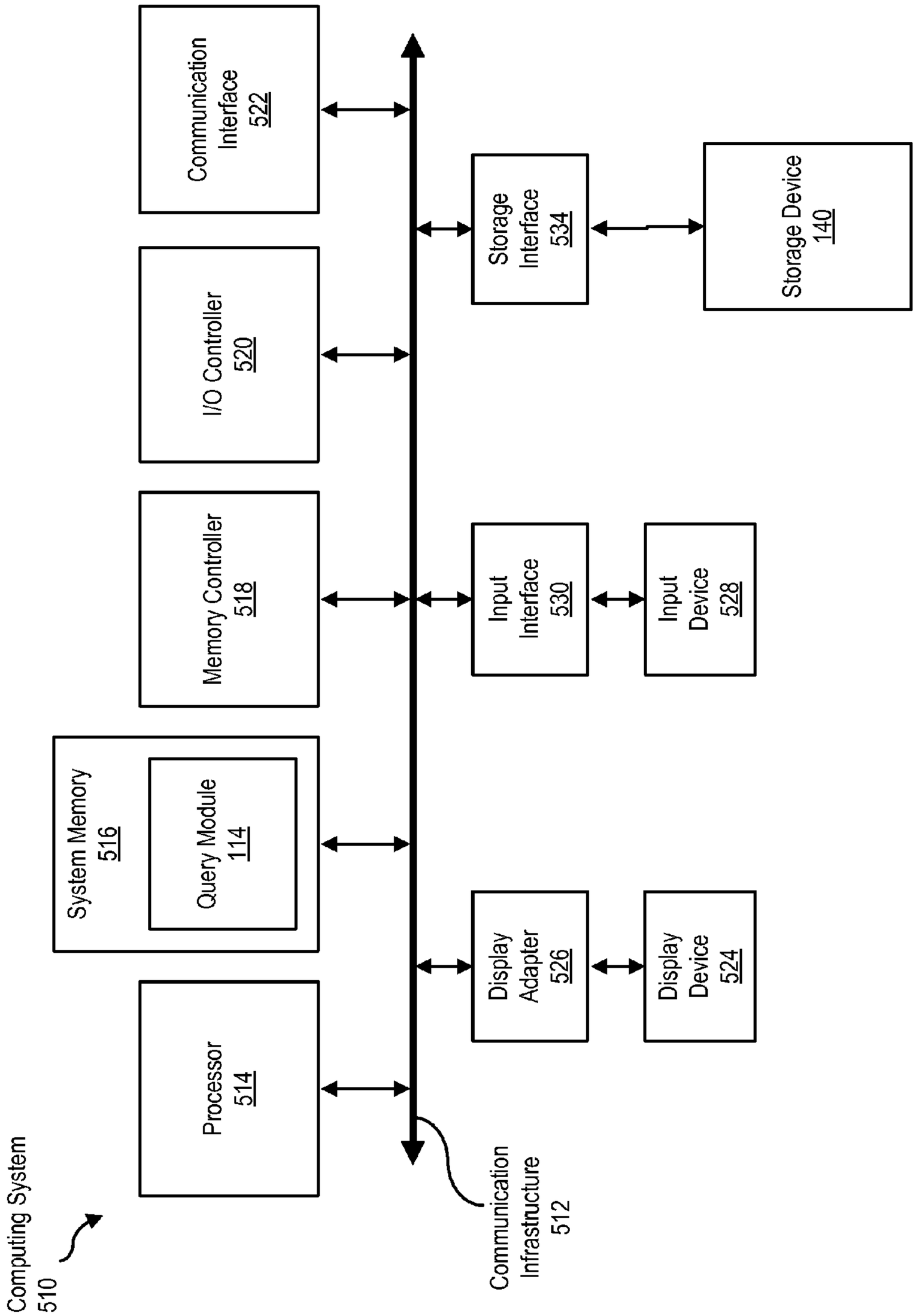

Computing System
510
Processor
514
System Memory
516
Query Module
114
Memory Controller
518
I/O Controller
520
Communication
Infrastructure
512
Communication
Interface
522
Storage
Interface
534
Storage Device
140
Input
Interface
530
Input
Device
528
Display
Adapter
526
Display
Device
524

FIG. 5

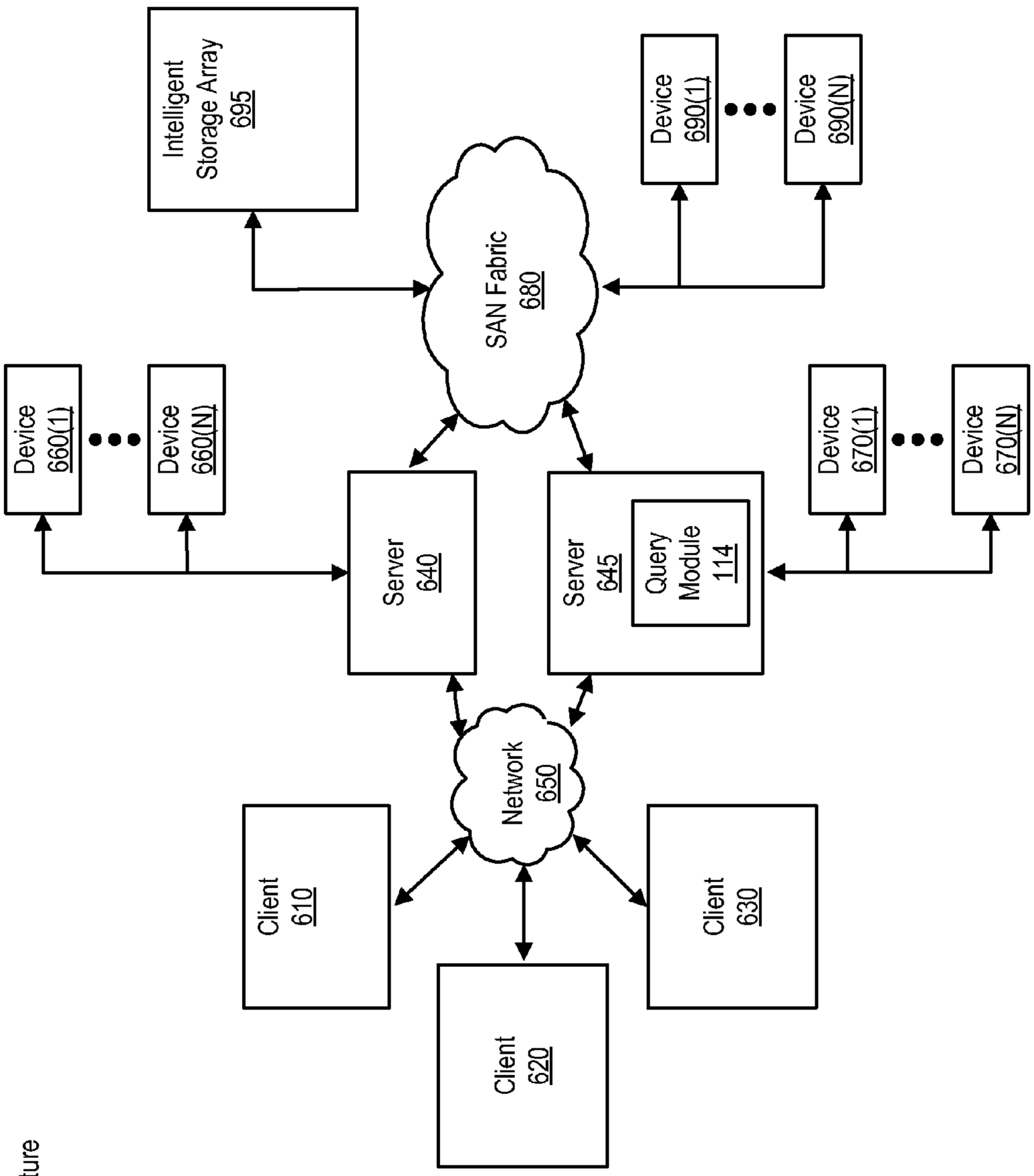

Intelligent Storage Array 695
Device 690(1)
Device 690(N)
SAN Fabric 680
Device 660(1)
Device 660(N)
Server 640
Server 645
Query Module 114
Device 670(1)
Device 670(N)
Network 650
Client 610
Client 630
Client 620
Network Architecture 600

FIG. 6

OPTIMIZED INDEX USAGE FOR DATA RESTORE

FIELD OF THE INVENTION

This invention relates to restoring data in a computer system, more particularly, to using pre-existing indexes for content-specific restore of backup and archive data.

DESCRIPTION OF THE RELATED ART

Businesses and other entities use data in performing their operations. Data protection and retention efforts, such as backup and archive operations, are integral to such entities. Backing up data involves creating a copy of the data in backup storage. Archiving data involves moving the data to archive storage. The value of backup and archive methods depends in large part on being able to efficiently restore data from the backup or archive storage. Restoring data means overwriting the data with data read from backup or archive storage.

SUMMARY OF THE INVENTION

Various systems and methods for restoring data using indexes are disclosed. For example, one method involves receiving a request that includes a restore criterion. The method involves identifying a storage object in a backup storage device that meets the restore criterion, in response to the request. Detecting the identity of the storage object involves sending a query with the restore criterion to a client computing device that includes an index. The method also involves responding to the request with information identifying the storage object.

In an embodiment, the restore criterion includes a portion of the content included in the storage object. The method also involves selecting which client computing device to query from several client computing devices based on a characteristic of the computing device.

The response that includes information identifying the storage object can include information identifying several storage objects. In such an example, the method involves receiving a selection of one of the storage objects. The method also involves comparing metadata associated with the storage object, such as when a backup of the storage object was created, with metadata associated with the client computing device.

An example of a system can include one or more processors and memory coupled to the one or more processors. The memory stores program instructions executable to perform a method like the one described above. Similarly, such program instructions can be stored upon a computer readable storage medium.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the present invention, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood, and its numerous objects, features and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. **1** is a block diagram of a system configured to perform restore of backup data using indexes, according to one embodiment of the present invention.

FIG. **2** is a flowchart of a method of performing a restore operation using indexes, according to one embodiment of the present invention.

FIG. **3** is a flowchart illustrating additional elements of a method of performing a restore operation using indexes, according to one embodiment of the present invention.

FIG. **4** is a flowchart illustrating additional elements of a method of performing a restore operation using indexes, according to one embodiment of the present invention.

FIG. **5** is a block diagram of a computing device, illustrating how a query module can be implemented in software, according to one embodiment of the present invention.

FIG. **6** is a block diagram of a networked system, illustrating how various computing devices can communicate via a network, according to one embodiment of the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments of the invention are provided as examples in the drawings and detailed description. It should be understood that the drawings and detailed description are not intended to limit the invention to the particular form disclosed. Instead, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

Backup software controls backup operations. Such software, in the form of a backup application, can be included on a media server. The backup application can control backup operations that back up data from a number of computing devices in a computing system. The computing devices from which the data is backed up are clients of the media server in the sense that the computing devices utilize backup services provided by the media server. The media server backs up data from the clients and provides access to the backed up data.

After detecting that data on a client is corrupted or otherwise invalid (e.g., as a result of a disaster, hardware failure, software failure, or user error) a user may wish to restore the data. To do so, a user can send a request from the client to the media server to have the data restored. The request includes information that identifies which data the user wants to copy from the backup data. For example, the request can specify a file name, a volume name, or a physical location. In response to the request, the media server can retrieve the data (e.g., from backup storage) and transmit the data to the client. The client can overwrite or otherwise replace the corrupt data, thus restoring the data.

When a user wishes to restore a storage object (e.g., a file, volume, block or range of blocks, or other portion of data) using data from backup storage or archive storage, the user searches the backup storage or archive storage for a backup copy or archive copy of the storage object. For example, a user can search backup storage for a particular file name. Typically, the user is unable to search the backup storage or archive storage to determine what content is included in the copy of the storage object located in such storage. For example, if a user wishes to restore a particular storage object the user can detect whether a backup copy or archive copy of the particular storage object exists in backup storage or archive storage. However, the user is typically unable to detect whether the specified storage object contains a particular word or phrase.

One way to overcome this limitation is to create an index for data stored in backup storage and archive storage. Then the user can search the index and determine what content is stored in the backup storage and archive storage. However, indexing such data stores can be a resource-intensive proposition, consuming significant time and processing power and most backup programs and archive programs do not provide this capability.

FIG. **1** is a block diagram of a system configured to perform content-specific restore of backup data using indexes. As shown, the system includes a media server **110**. Media server **110** is coupled to a computing device **120**. Media server **110** is also coupled to several clients **150**(**1**)-**150**(N) via network **130**. Network **130** can include a WAN (Wide Area Network), such as the Internet, one or more LANs (Local Area Networks), and/or one or more SANs (Storage Area Networks).

Media server **110** is a computing device such as a personal computer, laptop computer, server, personal digital assistant, cell phone, or the like. Media server **110** includes at least one processor **514** and a memory **516**. Media server **110** can include and/or be coupled (e.g., via a bus, network, or other appropriate interconnect) to a storage device **140**.

Storage device **140** provides persistent data storage, such that data stored in storage device **140** will remain stored even after storage device **140** is powered off. Storage device **140** can include one or more storage devices or storage appliances such as, for example, a solid state drive, a hard disk, a compact disc (CD), a digital versatile disc (DVD), sequential access media (e.g., tape storage), or other mass storage device, file serving appliance, or storage system (e.g., a redundant array of independent disks (RAID) system or an optical storage jukebox). Storage device **140** can also include one or more types of storage media, including solid state media (e.g., flash drives), optical media (e.g., CDs and DVDs), and magnetic media (e.g., hard disks or magnetic tape). In an embodiment, storage device **140** can be implemented using cloud storage, in which storage device **140** is a logical storage device to which physical storage device(s) are allocated on an as-needed and/or as-contracted basis. Storage device **140** can be formatted with the New Technology File System (NTFS), or any other available file system, such as file allocation table (FAT) or Veritas® File System (VxFS).

Storage device **140** includes backup data **142**. Backup data **142** includes one or more backup copies of one or more storage objects (e.g., storage objects located in data **154** of client **150**) and metadata concerning the storage objects. Examples of storage objects that can be backed up include a file, volume, disk, or other portion of data. Examples of metadata concerning the storage objects include size, priority, access permissions, author, time of creation, modification, and/or access, and the like. Backup data **142** can include one or more image files that contain a backed up copy of a storage object. An image file can include one or more full backups of the storage object, one or more incremental backups of a storage object, or a combination of the two. Backup data **142** can also include metadata identifying when the backup (e.g., image file) was created, access permissions, access times, priority, author, size, and the like. While FIG. **1** shows storage device **140** as including backup data **142**, in an embodiment, storage device **140** includes archive data in addition to or instead of backup data.

Memory **516** stores program instructions executable by processor **514** to implement a backup application **112** and a query module **114**. Backup application **112** performs backup and restore operations for clients **150**. Backup operations are performed to provide redundant copies of information. Backup operations include full backups, which create a point-in-time image of all of the data within a particular set of information, and incremental backups, which copy only those portions of the set of information that are modified during a particular time period. If the original copy of the information is lost, e.g., due to equipment failure or human error, the information can be restored from a backup copy made at an earlier point in time. In an embodiment, backup application **112** can also perform archive operations. Archive operations detect that data meets an archive creation condition, such as an age of the data, or how long ago the data was last accessed, and moves the data to archive storage in response to detecting the condition is met. In an embodiment, an archive application separate from backup application **112** can be include on media server **110**.

Backup application **112** can initiate backup operations automatically, for example, periodically, or in response to detecting the occurrence of some threshold condition, such as reaching a specified date or time. Backup application can also initiate backup operations manually, or in response to user input.

In an embodiment, performing a backup operation involves backup application **112** sending a message to a client **150**, specifically backup module **160**, informing client **150** that a backup operation is in progress. The message may include information identifying which data, e.g., from data **154**, is to be backed up. In response to the message, backup application **112** receives a copy of the specified data from client **150**. Backup application **112** then stores the copy of the data in backup data **142**. Backup application **112** can also create and store metadata, such as metadata describing when data in backup data **142** was created, accessed, modified, and the like.

In an embodiment, a backup operation may also involve performing operations on the data being copied to backup data **142**. For example, backup application **112** can format the data and store the data in a specific format, such as an image file. This format can differ from the format held by the data when stored on the client. Backup application **112** can also deduplicate and/or compress the data, which allows more effective utilization of storage resources. Backup application **112** can also encrypt the data, to ensure that the data is secure.

Backup application **112** can also perform restore operations. Backup application **112** can receive a request to restore data, e.g., from computing device **120** or more particularly from backup module **122**. The request can include information identifying a restore criterion. For example, the request can specify that data containing certain content, such as a word or phrase, be restored. The request can also specify that data that meets some other criterion should be restored. Such restore criteria can include the priority of data, the time data was created, accessed, or modified, the author of the data, the size of the data, and the like.

In response to backup application **112** receiving a restore request, query module **114** sends a message to one or more of clients **150** requesting that the client return information identifying any storage object stored on the client that meets the restore criteria. Query module **114** then detects any response from the clients. A response includes information identifying one or more storage objects stored on the client that meets the restore criterion. Such information can include a file name of the storage object, as well as metadata about the storage object, such as the time the storage object was created or modified. Based on the information from the clients, query module **114** can collect information identifying the storage objects on the clients that meet the restore criterion. Backup application **112** can identify copies of these storage objects that are stored in backup data **142** and create a list of these

copies. Such copies are likely to also meet the restore criterion. In an embodiment, the storage object is not stored on the client. For example, the storage object may have been removed from data **154** during an archive operation. However, the client can maintain index information for storage objects that have been moved to archive storage.

Backup application **112** then transmits the list to computing device **120**. Backup application **112** can receive from computing device **120** a selection that identifies of one or more storage objects from the list. Backup application **112** can locate copies of the selected storage objects in backup data **142**, and send the copies of the selected storage objects to computing device **120**.

Client **150** is a computing device such as a personal computer, laptop computer, server, personal digital assistant, cell phone, or the like. Client **150** includes application **152**, data **154**, index module **156**, index **158**, and backup module **160**. Application **152** can be a word processing program, email program, graphic editing program, database application, database manager, or the like. Application **152** accesses (e.g., by writing and/or reading) data, e.g., data **154**. In an embodiment, one or more clients (not shown) of client **150** run applications and access data **154**.

Index module **156** generates and maintains an index **158** of data **154**. Index module **156** can be an indexer such as Google Desktop, Microsoft Windows Search, or any other third-party indexer. In an embodiment, index **158** includes a subject index. A subject index includes a collection of words or phrases that are present in one or more storage objects, e.g., files, volumes, disks, or other portions of data. An index maps such words or phrases to the data objects in which the words or phrases are included. Index **158** can be implemented as a file that includes, for example, a list or a database.

Client **150** can also participate in backup operations. In particular, backup module **160** can initiate a backup operation. Backup module **160** can initiate backup operations automatically, for example, periodically, or in response to detecting the occurrence of some threshold condition, such as reaching a specified date or time or detecting a specified amount of data has been modified since a previous backup operation. Backup module **160** can also initiate backup operations manually, or in response to user input. Backup module **160** can also receive a message from backup application **112** indicating that a backup operation is in progress.

In response to detecting an ongoing backup operation, backup module **160** detects which data (e.g., data in data **154**) is to be backed up and sends the data to backup application **112**. In an embodiment, backup module **160** parses a message from backup application **112** to detect which data is to be backed up.

Backup module **160** can also participate in restore operations. Backup module **160** receives a restore message, e.g., from backup application **112**. The restore message specifies a restore criterion, such as a keyword. Backup module **160** issues a command to index module **156** to search index **158** and detect which storage objects identified in index **158** meet the restore criterion, e.g., contain the keyword. Index module **156** returns information to backup module **160** identifying one or more storage objects in data **154** that meet the criteria (if any do), as well as metadata indicating, for example, when these storage objects were last modified. Backup module **160** then transmits the information to backup application **112**.

Computing device **120** can participate in backup and restore operations. Computing device **120** is a computing device such as a personal computer, laptop computer, server, personal digital assistant, cell phone, or the like. Computing device **120** includes backup module **122**. Backup module **122** is configured to receive user input specifying restore criteria. Backup module **122** transmits the restore criteria to backup application **112**. Backup module **122** is also configured to display a list identifying one or more storage objects that can be used for a restore operation. Backup module **122** can receive user input selecting one or more of the displayed object(s) and transmit information identifying the selected storage object(s) to backup application **112**. While computing device **120** is illustrated as a separate computing device, the functionality included in computing device **120** can be included in one or more of the other components of FIG. **1**, such as media server **110** or one or more of clients **150**.

Backup module **122** is also configured to display (e.g., to a user) information regarding an ongoing restore operation. For example, backup module **122** can indicate that no storage objects were found in data **154** or backup storage that meet the specified restore criteria. Backup module **122** can also display status messages indicating, for example, that a restore operation is in progress, or has completed successfully.

The system of FIG. **1** enables the media server to restore only the data that is actually desired. This has the potential to dramatically reduce the amount of data that is restored. This may speed up restore operations, free up transmission bandwidth, and reduce demands on media server processing bandwidth. This may enable other backup operations to proceed more quickly. The media server does not incur the overhead associated with generating, organizing, storing, and searching index information, as these tasks are performed by the clients.

FIG. **2** is a flowchart of a method of performing a restore operation using indexes. The method can be performed in a computing environment, e.g., computing environment **100** of FIG. **1**. The method involves searching a number of clients, such as clients **150**, for information that identifies the location of a storage object in data **154** that matches a specified restore criterion and restoring data using a backup copy of the storage object. The method begins at **205**, with initiating a restore operation in response to receiving a restore request. The restore operation can be initiated by a backup application, e.g., backup application **112** of FIG. **1**. In an embodiment, the backup application initiates the restore operation in response to a restore request from a requestor, e.g., a user of computing device **120** of FIG. **1**.

The restore request identifies one or more restore criteria to be used to indirectly identify one or more storage objects stored in backup storage (e.g., backup storage **142** of FIG. **1**) to be used to restore a storage object, e.g. a storage object stored in data **154** on a client such as one of clients **150** of FIG. **1**. The restore criteria can include, for example, a keyword, a user name, a date and/or time the storage object was created, modified, accessed, and the like.

The restore request can also specify one or more search parameters. For example, the restore request can specify that only storage objects from a specific machine or set of machines should be considered. If the request contains search parameters, the backup application modifies the search at **225**. Otherwise, the method proceeds to **235**, where the backup application identifies one or more storage objects that meet the restore criteria. FIG. **3** provides more details regarding identifying a storage object that meets the restore criteria.

In response to receiving a request to identify one or more storage objects that meet a restore criterion (e.g., storage objects that contain a given keyword) the backup application detects where in backup storage such storage objects can be found. As noted above, the backup application may be unable to perform a content search on the backup data if the backup data is not indexed. Regardless, the backup data comprises

copies of storage objects from one or more clients, e.g., clients **150** of FIG. **1** and one or more of the clients can include indexes of the data in the storage objects, e.g., index **158** of FIG. **1**. The indexes are generated by an index module on the client, e.g., index module **156** of FIG. **1**. To indirectly detect which backup data (if any) meets the restore criterion, the backup application can interact with the clients to search the indexes maintained by the clients. Since the data in the backup storage includes copies of the storage objects on the clients, an index of the clients' storage objects is effectively an index of the backup data. Searching an index of the clients' storage objects for data that meets the restore criterion can result in identifying storage objects on the clients that meet the restore criterion. Since the storage objects on the clients were copied to backup storage, these search results can be used to identify storage objects located in backup storage that, by default, also meet the restore criterion.

At **310**, the backup application detects which clients are participating clients. This can involve the backup application on the media server sending a message to a backup module on a client. The backup module on the client detects whether the client includes an index module and index. If so, the backup module sends a reply message to the backup application indicating that the client has indexed data and is a participating client. A participating client is a client that can be queried by backup application to identify storage objects based on a restore criterion. This involves the client searching its index in response to a query to identify storage objects that include a specified keyword.

If the backup module that requested the query detects that a client is not a participating client (e.g., does not include an index module) the backup module can send a message to the backup application including this information. In an embodiment, a participating client sends a message indicating participation without first receiving a message from the backup application. For example, when a client comes online, a backup module on the client can detect that the client includes an index module and convey a message with this information to the backup application. As another example, a backup module on a client can send such a message in response to detecting the installation of an index module on the client and generation of an index.

Detecting which clients are participating can also involve detecting a format of the index maintained by each participating client. Different index modules can produce different types of indexes. Different indexes can include different file types and data structures to store the index.

The backup application receives the reply messages and stores information indicating which clients in the computing system are participating clients. At **320**, the backup application transmits a query to the participating clients. The backup application is configured to communicate with a number of types of clients having various types of index modules and indexes. For example, a first client can include an indexer that produces an index having a first format. A second client can include a different indexer (e.g., developed by a different vendor) that produces an index having a format different from the first format. The backup application can detect the type and format of a client's index and can modify the backup application's behavior to be compatible with a number of different types of indexers and indexes. For example the backup application can generate each query based on the type of index maintained by the participating client.

A query is based on a restore criterion. For example, backup application can send a query that includes a specific word or phrase, a type of storage object, an author, date of creation, priority, and the like. The backup application can send messages to multiple participating clients simultaneously, or nearly so, such that the participating clients can search their indexes concurrently, or in parallel.

The queries sent by the backup application are received by backup module on the participating clients. A backup module on a given participating client communicates with the participating client's indexer and instructs the index module to search the participating client's index for storage objects that meet the restore criterion. The index module responds with information identifying any storage objects that do so, as well as metadata regarding the storage objects, such as the last time the storage objects were accessed (e.g., modified). The backup module transmits this information to the backup application.

At **330**, the backup application receives a response from a participating client that includes the results of the client's index module's search. The backup application can receive and process responses from multiple participating clients concurrently, in parallel, or sequentially. At **340**, the backup application detects whether the response indicates that the participating client's index module located any storage objects in the client's data that meet the restore criterion. If so, the backup application detects whether the identified storage objects have backup copies suitable for use in a restore operation, and thus that the results are valid, at **350**. This involves comparing metadata received from the participating client's backup module (such as when the participating client last modified the storage object) with metadata stored by the backup application (e.g., with the backup data), such as when the backup copy of the storage object was stored in the backup data. The backup application can compare the date the storage object was last modified on the participating client with the date the backup of that storage object was created. If the storage object was modified on the participating client after the backup copy of the storage object was made, the backup copy of the storage object may not actually meet the restore criterion.

Consider an example in which the restore criterion specified a keyword, and the participating client returned a file name of a file on the participating client that contains the keyword. If the backup application detects that the file on the participating client was modified after a backup copy was made of the file, it is possible that the backup copy of the file does not contain the keyword (e.g., if the keyword was added to the file subsequent to the backup copy of the file being created). In such an example, the information identifying a storage object as meeting the restore criterion is considered invalid and the backup application ignores the information.

If a storage object that meets the restore criterion is found and is valid (e.g., was not modified on the participating client subsequent to a backup copy of the storage object being created and stored in backup storage), the backup application adds the information identifying the storage object to a list of storage objects that meet the restore criterion, at **360**. The list includes, for example, file names of files stored in backup storage that include a specified keyword.

At **370**, the backup application detects whether there are more participating clients. This involves detecting whether a response has been received from each participating client that the backup application queried. If the backup application has not received a response from each participating client queried, the method returns to **330**, where the backup application receives any additional responses. If the backup application has received responses from all participating clients the backup application queried, the method returns to FIG. **2**, at **245**.

At **245**, the backup application transmits the results of identifying storage objects that meet the restore criterion to the requestor, e.g., computing device **120** of FIG. **1**. The results can include information identifying one or more storage objects stored in backup storage that meet the restore criteria. Alternatively, the results can indicate that no such storage objects were identified as being present in backup storage.

At **255**, the backup application receives a selection from the requestor. The selection can include information selecting one or more storage objects identified in the results the backup application sent. The selected storage object is restored at **265**, discussed in more detail with regard to FIG. **4**.

In response to receiving information selecting a storage object, the backup application detects, at **410**, whether the selection includes information identifying a location where the backup copy of the storage object can be found. A storage object that meets the restore criterion can be found in multiple locations. Similarly, multiple backup copies of such a storage object can exist. For example, a backup copy of the storage object can be found in a backup of a first client as well as in a backup of a second client. Similarly, a backup copy of the storage object can be found both in an older version of a backup and a newer version of a backup. In such an example, the selection of which backup copy of the storage object to restore can include information that identifies which of multiple backup copies of the storage object is selected to be restored.

If no location is specified by the requestor, the backup application identifies a location where a backup copy of the storage object can be found and will be read from. If there is only a single backup copy of the selected storage object in backup storage, the backup application selects the single location. If multiple backup copies of the storage object exist in multiple locations, the backup application selects a location from the multiple locations. The selection can be based on metadata, such as creation date of the storage object or backup that includes the storage object, or a size of the backup copy of the storage object. For example, the backup application can select the smaller of two backup copies of a storage object as restoring the smaller backup copy of the storage object requires less time and computing resources (e.g., transmission bandwidth and processor cycles).

At **430**, the backup application reads the selected storage object from backup storage. The backup application then transmits the storage object to the requestor at **440**. Once the storage object has been transmitted to the requestor, the requestor can use the storage object to restore data, for example a corrupted file on a computing device.

FIG. **5** is a block diagram of a computing device, illustrating how a query module **114** can be implemented in software. Computing system **510** broadly represents any single or multi-processor computing device or system capable of executing computer-readable instructions. Examples of computing system **510** include, without limitation, any one or more of a variety of devices including workstations, personal computers, laptops, client-side terminals, servers, distributed computing systems, handheld devices (e.g., personal digital assistants and mobile phones), network appliances, storage controllers (e.g., array controllers, tape drive controller, or hard drive controller), and the like. In its most basic configuration, computing system **510** may include at least one processor **514** and a system memory **516**. By executing the software that implements a query module **114**, computing system **510** becomes a special purpose computing device that is configured to restore backup data using indexes.

Processor **514** generally represents any type or form of processing unit capable of processing data or interpreting and executing instructions. In certain embodiments, processor **514** may receive instructions from a software application or module. These instructions may cause processor **514** to perform the functions of one or more of the embodiments described and/or illustrated herein. For example, processor **514** may perform and/or be a means for performing all or some of the operations described herein. Processor **514** may also perform and/or be a means for performing any other operations, methods, or processes described and/or illustrated herein.

System memory **516** generally represents any type or form of volatile or non-volatile storage device or medium capable of storing data and/or other computer-readable instructions. Examples of system memory **516** include, without limitation, random access memory (RAM), read only memory (ROM), flash memory, or any other suitable memory device. In one example, program instructions implementing a query module **114** may be loaded into system memory **516**.

In certain embodiments, computing system **510** may also include one or more components or elements in addition to processor **514** and system memory **516**. For example, as illustrated in FIG. **5**, computing system **510** may include a memory controller **518**, an Input/Output (I/O) controller **520**, and a communication interface **522**, each of which may be interconnected via a communication infrastructure **512**. Communication infrastructure **512** generally represents any type or form of infrastructure capable of facilitating communication between one or more components of a computing device. Examples of communication infrastructure **512** include, without limitation, a communication bus (such as an Industry Standard Architecture (ISA), Peripheral Component Interconnect (PCI), PCI express (PCIe), or similar bus) and a network.

Memory controller **518** generally represents any type or form of device capable of handling memory or data or controlling communication between one or more components of computing system **510**. For example, in certain embodiments memory controller **518** may control communication between processor **514**, system memory **516**, and I/O controller **520** via communication infrastructure **512**. In certain embodiments, memory controller **518** may perform and/or be a means for performing, either alone or in combination with other elements, one or more of the operations or features described and/or illustrated herein.

I/O controller **520** generally represents any type or form of module capable of coordinating and/or controlling the input and output functions of a computing device. For example, in certain embodiments I/O controller **520** may control or facilitate transfer of data between one or more elements of computing system **510**, such as processor **514**, system memory **516**, communication interface **522**, display adapter **526**, input interface **550**, and storage interface **554**.

Communication interface **522** broadly represents any type or form of communication device or adapter capable of facilitating communication between computing system **510** and one or more additional devices. For example, in certain embodiments communication interface **522** may facilitate communication between computing system **510** and a private or public network including additional computing systems. Examples of communication interface **522** include, without limitation, a wired network interface (such as a network interface card), a wireless network interface (such as a wireless network interface card), a modem, and any other suitable interface. In at least one embodiment, communication interface **522** may provide a direct connection to a remote server

via a direct link to a network, such as the Internet. Communication interface **522** may also indirectly provide such a connection through, for example, a local area network (such as an Ethernet network), a personal area network, a telephone or cable network, a cellular telephone connection, a satellite data connection, or any other suitable connection.

In certain embodiments, communication interface **522** may also represent a host adapter configured to facilitate communication between computing system **510** and one or more additional network or storage devices via an external bus or communications channel. Examples of host adapters include, without limitation, Small Computer System Interface (SCSI) host adapters, Universal Serial Bus (USB) host adapters, Institute of Electrical and Electronics Engineers (IEEE) 1594 host adapters, Serial Advanced Technology Attachment (SATA), Serial Attached SCSI (SAS), and external SATA (eSATA) host adapters, Advanced Technology Attachment (ATA) and Parallel ATA (PATA) host adapters, Fibre Channel interface adapters, Ethernet adapters, or the like.

Communication interface **522** may also allow computing system **510** to engage in distributed or remote computing. For example, communication interface **522** may receive instructions from a remote device or send instructions to a remote device for execution.

As illustrated in FIG. **5**, computing system **510** may also include at least one display device **524** coupled to communication infrastructure **512** via a display adapter **526**. Display device **524** generally represents any type or form of device capable of visually displaying information forwarded by display adapter **526**. Similarly, display adapter **526** generally represents any type or form of device configured to forward graphics, text, and other data from communication infrastructure **512** (or from a frame buffer, as known in the art) for display on display device **524**.

As illustrated in FIG. **5**, computing system **510** may also include at least one input device **528** coupled to communication infrastructure **512** via an input interface **550**. Input device **528** generally represents any type or form of input device capable of providing input, either computer or human generated, to computing system **510**. Examples of input device **528** include, without limitation, a keyboard, a pointing device, a speech recognition device, or any other input device.

As illustrated in FIG. **5**, computing system **510** may also include a data storage device **533** coupled to communication infrastructure **512** via a storage interface **534**. Storage device **533** generally represents any type or form of storage device or medium capable of storing data and/or other computer-readable instructions. For example, storage device **533** may include a magnetic disk drive (e.g., a so-called hard drive), a floppy disk drive, an optical disk drive, a flash drive, or the like. Storage interface **534** generally represents any type or form of interface or device for transferring data between storage device **533** and other components of computing system **510**.

In certain embodiments, storage device **533** may be configured to read from and/or write to a removable storage unit configured to store computer software, data, or other computer-readable information. Examples of suitable removable storage units include, without limitation, a floppy disk, a magnetic tape, an optical disk, a flash memory device, or the like. Storage device **533** may also include other similar structures or devices for allowing computer software, data, or other computer-readable instructions to be loaded into computing system **510**. For example, storage device **533** may be configured to read and write software, data, or other computer-readable information. Storage device **533** may also be a part of computing system **510** or may be a separate device accessed through other interface systems.

Many other devices or subsystems may be connected to computing system **510**. Conversely, all of the components and devices illustrated in FIG. **5** need not be present to practice the embodiments described and/or illustrated herein. The devices and subsystems referenced above may also be interconnected in different ways from that shown in FIG. **5**.

Computing system **510** may also employ any number of software, firmware, and/or hardware configurations. For example, one or more of the embodiments disclosed herein may be encoded as a computer program (also referred to as computer software, software applications, computer-readable instructions, or computer control logic) on a computer-readable storage medium. Examples of computer-readable storage media include magnetic-storage media (e.g., hard disk drives and floppy disks), optical-storage media (e.g., CD- or DVD-ROMs), electronic-storage media (e.g., solid-state drives and flash media), and the like. Such computer programs can also be transferred to computing system **510** for storage in memory via a network such as the Internet or upon a carrier medium.

The computer-readable medium containing the computer program may be loaded into computing system **510**. All or a portion of the computer program stored on the computer-readable medium may then be stored in system memory **516** and/or various portions of storage devices **532** and **533**. When executed by processor **514**, a computer program loaded into computing system **510** may cause processor **514** to perform and/or be a means for performing the functions of one or more of the embodiments described and/or illustrated herein. Additionally or alternatively, one or more of the embodiments described and/or illustrated herein may be implemented in firmware and/or hardware. For example, computing system **510** may be configured as an application specific integrated circuit (ASIC) adapted to implement one or more of the embodiments disclosed herein.

FIG. **6** is a block diagram of a network architecture **600** in which client systems **610**, **620**, and **630** and servers **640** and **645** may be coupled to a network **650**. Client systems **610**, **620**, and **630** generally represent any type or form of computing device or system.

Similarly, servers **640** and **645** generally represent computing devices or systems, such as application servers or database servers implemented on a computing device such as computing system **510** in FIG. **5**, configured to provide various database services and/or run certain software applications. Network **650** generally represents any telecommunication or computer network including, for example, an intranet, a wide area network (WAN), a local area network (LAN), a personal area network (PAN), or the Internet. In one example, servers **640** and/or **645** may include a query module **114** as shown in FIG. **1**.

As illustrated in FIG. **6**, one or more storage devices **660**(**1**)-(N) may be directly attached to server **640**. Similarly, one or more storage devices **670**(**1**)-(N) may be directly attached to server **645**. Storage devices **660**(**1**)-(N) and storage devices **670**(**1**)-(N) generally represent any type or form of storage device or medium capable of storing data and/or other computer-readable instructions. In certain embodiments, storage devices **660**(**1**)-(N) and storage devices **670**(**1**)-(N) may represent network-attached storage (NAS) devices configured to communicate with servers **640** and **645** using various protocols, such as Network File System (NFS), Server Message Block (SMB), or Common Internet File System (CIFS).

Servers **640** and **645** may also be connected to a storage area network (SAN) fabric **680**. SAN fabric **680** generally

represents any type or form of computer network or architecture capable of facilitating communication between multiple storage devices. SAN fabric **680** may facilitate communication between servers **640** and **645** and a plurality of storage devices **690**(**1**)-(N) and/or an intelligent storage array **695**. SAN fabric **680** may also facilitate, via network **650** and servers **640** and **645**, communication between client systems **610**, **620**, and **630** and storage devices **690**(**1**)-(N) and/or intelligent storage array **695** in such a manner that devices **690**(**1**)-(N) and array **695** appear as locally attached devices to client systems **610**, **620**, and **630**. As with storage devices **660**(**1**)-(N) and storage devices **670**(**1**)-(N), storage devices **690**(**1**)-(N) and intelligent storage array **695** generally represent any type or form of storage device or medium capable of storing data and/or other computer-readable instructions.

In certain embodiments, and with reference to computing system **510** of FIG. **5**, a communication interface, such as communication interface **522** in FIG. **5**, may be used to provide connectivity between each client systems **610**, **620**, and **630** and network **650**. Client systems **610**, **620**, and **630** may be able to access information on server **640** or **645** using, for example, a web browser or other client software. Such software may allow client systems **610**, **620**, and **630** to access data hosted by server **640**, server **645**, storage devices **660**(**1**)-(N), storage devices **670**(**1**)-(N), storage devices **690**(**1**)-(N), or intelligent storage array **695**. Although FIG. **6** depicts the use of a network (such as the Internet) for exchanging data, the embodiments described and/or illustrated herein are not limited to the Internet or any particular network-based environment.

In at least one embodiment, all or a portion of one or more of the embodiments disclosed herein may be encoded as a computer program and loaded onto and executed by server **640**, server **645**, storage devices **660**(**1**)-(N), storage devices **670**(**1**)-(N), storage devices **690**(**1**)-(N), intelligent storage array **695**, or any combination thereof. All or a portion of one or more of the embodiments disclosed herein may also be encoded as a computer program, stored in server **640**, run by server **645**, and distributed to client systems **610**, **620**, and **630** over network **650**.

In some examples, all or a portion of the computing devices in FIGS. **1**, **5**, and **6** may represent portions of a cloud-computing or network-based environment. Cloud-computing environments may provide various services and applications via the Internet. These cloud-based services (e.g., software as a service, platform as a service, infrastructure as a service, etc.) may be accessible through a web browser or other remote interface. Various functions described herein may be provided through a remote desktop environment or any other cloud-based computing environment.

In addition, one or more of the components described herein may transform data, physical devices, and/or representations of physical devices from one form to another. For example, the query module of FIG. **1** may transform behavior of a computing device in order to cause the computing device to restore backup data using indexes.

Although the present invention has been described in connection with several embodiments, the invention is not intended to be limited to the specific forms set forth herein. On the contrary, it is intended to cover such alternatives, modifications, and equivalents as can be reasonably included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A method comprising:

receiving a request from a first computing device at a backup storage device,

wherein

the request comprises a restore criterion;

transmitting a query from the backup storage device to at least one client computing device of a plurality of client computing devices in response to the receiving the request, wherein

each client computing device of the plurality of client computing devices comprises a respective index of a respective plurality of storage objects indexed by the each client computing device;

receiving a reply to the query, wherein

the reply is received by the backup storage device from the at least one client computing device of the plurality of client computing devices, and

the reply comprises information identifying at least one storage object stored in the at least one client computing device that satisfies the restore criterion;

identifying whether a backup copy of the at least one storage object is stored in the backup storage device; and

transmitting

information to the first computing device, wherein the information identifies the backup copy of the at least one storage object.

2. The method of claim **1**, wherein

the restore criterion comprises a portion of content included in the at least one storage object.

3. The method of claim **1**, wherein

the information identifies a plurality of backup copies of the at least one storage object.

4. The method of claim **1**, further comprising:

selecting the at least one client computing device from the plurality of client computing devices based on a characteristic of the client computing device.

5. The method of claim **4**, further comprising

sending the query to the each client computing device of the at least one client computing device.

6. The method of claim **1**, further comprising:

receiving a selection of the backup copy of the at least one storage object;

copying data from the backup copy of the at least one storage object in response to the receiving the selection.

7. The method of claim **1**, further comprising:

comparing metadata associated with the at least one storage object with metadata associated with the at least one client computing device, wherein

the metadata associated with the at least one storage object indicates when the backup copy of the at least one storage object was created.

8. A non-transitory computer readable storage medium storing program instructions executable to:

receive a request from a first computing device at a backup storage device, wherein

the request comprises a restore criterion;

transmit a query from the backup storage device to at least one client computing device of a plurality of client computing devices in response to receiving the request, wherein

each client computing device of the plurality of client computing devices comprises a respective index of a respective plurality of storage objects indexed by the each client computing device;

receive a reply to the query, wherein

the reply is received by the backup storage device from the at least one client computing device of the plurality of client computing devices, and

the reply comprises information identifying at least one storage object stored in the at least one client computing device that satisfies the restore criterion;

identify whether a backup copy of the at least one storage object is stored in the backup storage device; and

transmit

information to the first computing device, wherein the information identifies the backup copy of the at least one storage object.

9. The non-transitory computer readable storage medium of claim **8**, wherein

the restore criterion comprises a portion of content included in the at least one storage object.

10. The non-transitory computer readable storage medium of claim **8**, wherein

the information identifies a plurality of backup copies of the at least one storage object.

11. The non-transitory computer readable storage medium of claim **8**, wherein the program instructions are further executable to:

select the at least one client computing device from the plurality of client computing devices based on a characteristic of the at least one client computing device.

12. The non-transitory computer readable storage medium of claim **11**, wherein the program instructions are further executable to:

send the query to the each client computing device of the at least one client computing device.

13. The non-transitory computer readable storage medium of claim **8**, wherein the program instructions are further executable to:

receive a selection of the backup copy of the at least one storage object;

copy data from the backup copy of the at least one storage object in response to receiving the selection.

14. The non-transitory computer readable storage medium of claim **8**, wherein the program instructions are further executable to:

compare metadata associated with the backup copy of the at least one storage object with metadata associated with the at least one client computing device, wherein

the metadata associated with the backup copy of the at least one storage object indicates when the backup copy of the at least one storage object was created.

15. A system comprising:

one or more processors; and

a memory coupled to the one or more processors, wherein

the memory stores program instructions executable by the one or more processors to:

receive a request from a first computing device at a backup storage device, wherein

the request comprises a restore criterion;

transmit a query from the backup storage device to at least one client computing device of a plurality of client computing devices in response to receiving the request, wherein

each client computing device of the plurality of client computing devices comprises a respective index of a respective plurality of storage objects indexed by the each client computing device;

receive a reply to the query, wherein

the reply is received by the backup storage device from the at least one client computing device of the plurality of client computing devices, and

the reply comprises information identifying at least one storage object stored in the at least one client computing device that satisfies the restore criterion;

identify whether a backup copy of the at least one storage object is stored in the backup storage device; and

transmit

information to the first computing device, wherein

the information identifies the backup copy of the at least one storage object.

16. The system of claim **15**, wherein

the restore criterion comprises a portion of content included in the at least one storage object.

17. The system of claim **15**, wherein

the information identifies a plurality of backup copies of the at least one storage object.

18. The system of claim **15**, wherein the program instructions are further executable to:

select the at least one client computing device from the plurality of client computing devices based on a characteristic of the at least one client computing device.

19. The system of claim **15**, wherein the program instructions are further executable to:

receive a selection of the backup copy of the at least one storage object;

copy data from the backup copy of the at least one storage object in response to receiving the selection.

20. The system of claim **15**, wherein the program instructions are further executable to:

compare metadata associated with the backup copy of the at least one storage object with metadata associated with the at least one client computing device, wherein

the metadata associated with the backup copy of the at least one storage object indicates when the backup copy of the at least one storage object was created.

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